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Voith Hydro

Anatomy of a Kaplan blade weld repair.

In Place Repair of a 9000Lb Section Broken During Generating Operations

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PUBLIC INFORMATION NOTICE

- **Release #PA-2009-04 February 13, 2009**
- **Stockton Dam Power Generation Halted**

Stockton, Missouri – The U.S. Army Corps of Engineers today announced that hydroelectric electricity generation will not be available from Stockton Dam for an unknown period of time.

On Wednesday, February 4th, the plant was shut down due to unusual vibration from the turbine. An inspection by divers and further inspections by a team of engineers inside the dam's water passageways revealed that a large portion of one of the six blades on the turbine had broken and three additional blades show signs of distress. Initial indications are that the blade failure is due to both metal fatigue and the age of the turbine.

During the repairs, the dam will remain fully functional for flood control and all other purposes, and the safety of the dam is not threatened by the inability of the turbine to generate electricity.

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- **Stockton Dam Power Generation Halted**

Stockton Dam has one turbine and first generated power in 1973. The turbine last received a detailed inspection in 2005. In 2008, Stockton Dam generated 88 million kilowatt hours of electricity with an approximate value of $13.4 million.

Capacity and energy from the Stockton Dam is marketed by Southwestern Power Administration, an agency within the Department of Energy, to public bodies and cooperatives in Arkansas, Kansas, Louisiana, Missouri, Oklahoma, and Texas. The loss of the renewable electricity generated by Stockton Dam may be offset by generation from thermal generation sources.

Engineers are currently evaluating all possibilities to repair the turbine. The process is expected to take in excess of one year due to the complexity of disassembly, repair, and reassembly of the generator and turbine

Post Event Inspection by the COE

- Found blade number four (#4) had fractured leaving the broken section in the draft tube elbow.
- Revealed that cracking originated from the pressure side trailing edge at the junction of the blade and blade trunnion.
- Cracking in two additional blades forming at the same location as the broken blade (indications were later found in all five (5) unbroken blades).
- The fractured section weighed approximately 9000 Lbs

Fractured Blade Stub
Adjacent Blade
Turbine Hub

Repair Options

- Repair or replace the existing runner. USACE chose to do both.
- A two (2) year lead time to replace the runner dictated repair to prevent loss of two years of generating capacity/revenue
- Unit disassembly would add five (5) months of outage schedule plus risks to the generator; COE elected for **'in place'** repair of blade number four.
- COE also specified and solicited a replacement runner. A contract was placed with Voith Hydro with delivery due in 2012.
- A repair solicitation notice was issued September 15th, 2009 requesting qualified contractors.
- COE separately contracted to remove the broken segment of the blade from the draft tube.
- Divers and riggers retrieved the blade segment from the draft tube elbow segment relocating it to the powerhouse floor.

Solicitation Response

- The Peak Hydro Services team analyzed the repair scenario provided by the COE to prepare a winning response.
- Labor, materials and subcontracting requirements were identified; submission documents prepared.
- Less than three weeks was provided to prepare the entire package.
- Necessitating hundreds of man hours and a team of seven individuals.
- The team efforts were led by Mr. Scott Smith and Mr. Sam Perry.
- Resulted in Award

Project Management, Scheduling and Approach

- The project was managed from Peak Hydro Services main office in Chattanooga, TN.
- A full time on site Project Manager was utilized throughout the outage to interface directly with USACE site personnel and subcontractors.
- To meet the completion date of September 2010 the broken blade segment was prepared in parallel the stub segment in the Kaplan Hub.
- It was more cost effective to ship the broken segment to Chattanooga to prepare for re-attachment.
- Site team mobilized to Stockton June 9, 2010, consisting of three Welder/Millwrights, Foremen, Site Safety and Health Officer and Project Manager.

Pre-blade reattachment activities

- Chemical composition analysis confirmed the blade material was constructed of A148 class 80-50 low carbon steel. The original specification was MIL QQ-S-681d 80-50 Carbon steel (discontinued) - replaced by ASTM A148 class 80-50 .
- Welding Procedure Specification (WPS) was qualified to Section IX of the ASME Boiler and Pressure Vessel Code.
- Due to the 10.25 inch (max) thickness of the blade cross section the Procedure Qualification Record (PQR) testing used 8 inches thick base material.
- Qualification testing was performed at the Voith Hydro (Peak Hydro Services is a wholly owned subsidiary of Voith Hydro) facility in York, PA.

Welding Process

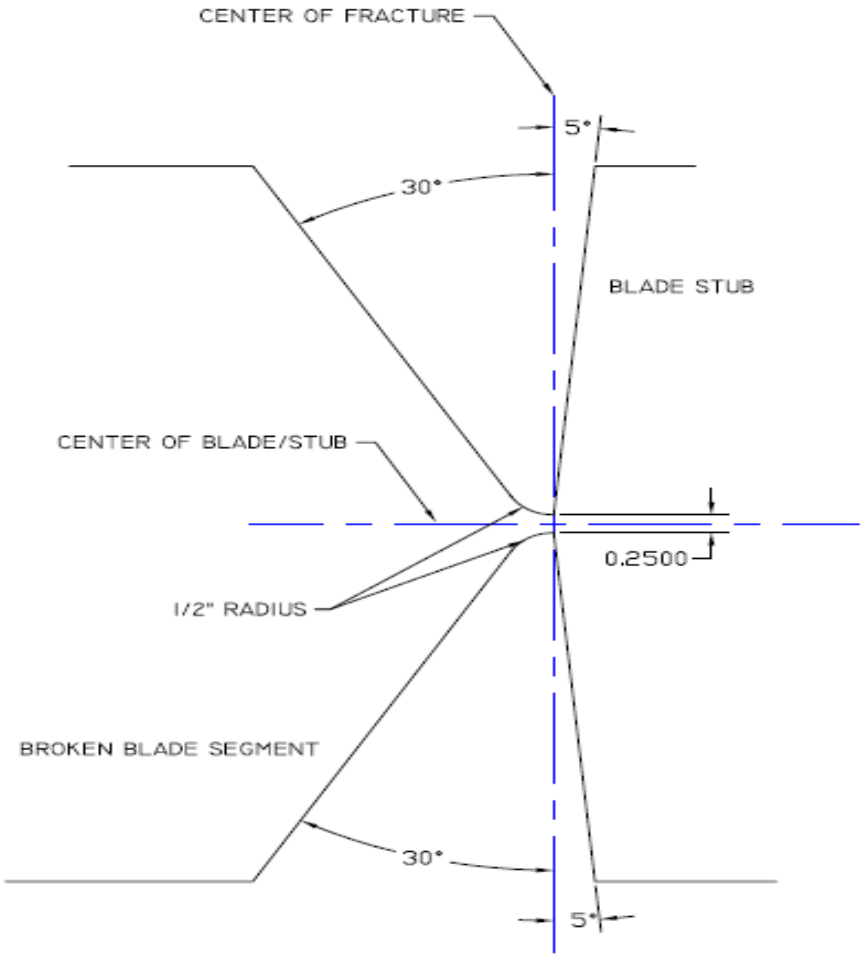
- For efficiency, Peak Hydro Services advocated manual and/or semi automatic Flux Core Arc Welding with 75%-25% Argon/CO2 gas shield.
- AWS E81T-1 0.045” and 1/16” diameter flux core filler wire were selected for the blade reattachment.
- Arc Transfer mode was globular using both string beads and weave passes.
- The process was qualified for all positions.
- Distortion was controlled by balancing of the weld deposits.
- Stop/starts were staggered. Rigorous inter-pass cleaning procedures ensured quality met or exceeded ASME standards.
- High carbon equivalent (CE) content of the blade material required pre-heat and inter-pass temperature at 350ºF. Post heat treatment temperature between 400-500ºF for 12 hours.
- The PQR Weld essential variables that were used to prepare the Welding Procedure Specification (WPS) that would be used to complete the blade repair .

Sequence

- The broken blade segment was shipped to Chattanooga, TN for weld joint preparation and non-destructive examination (NDE).
- The site team prepared the blade stub.
- A modified double Vee joint design was employed reducing volume, deposited material and total heat input.
- Three areas of the blade fracture length and blade stub were left unprepared. These areas were would be used for joint abutting and alignment of the two pieces.
- NDE was performed on the prepared surfaces of the weld joint to ensure no cracks remained.

Blade arriving back to site after NDE and Joint Preparation

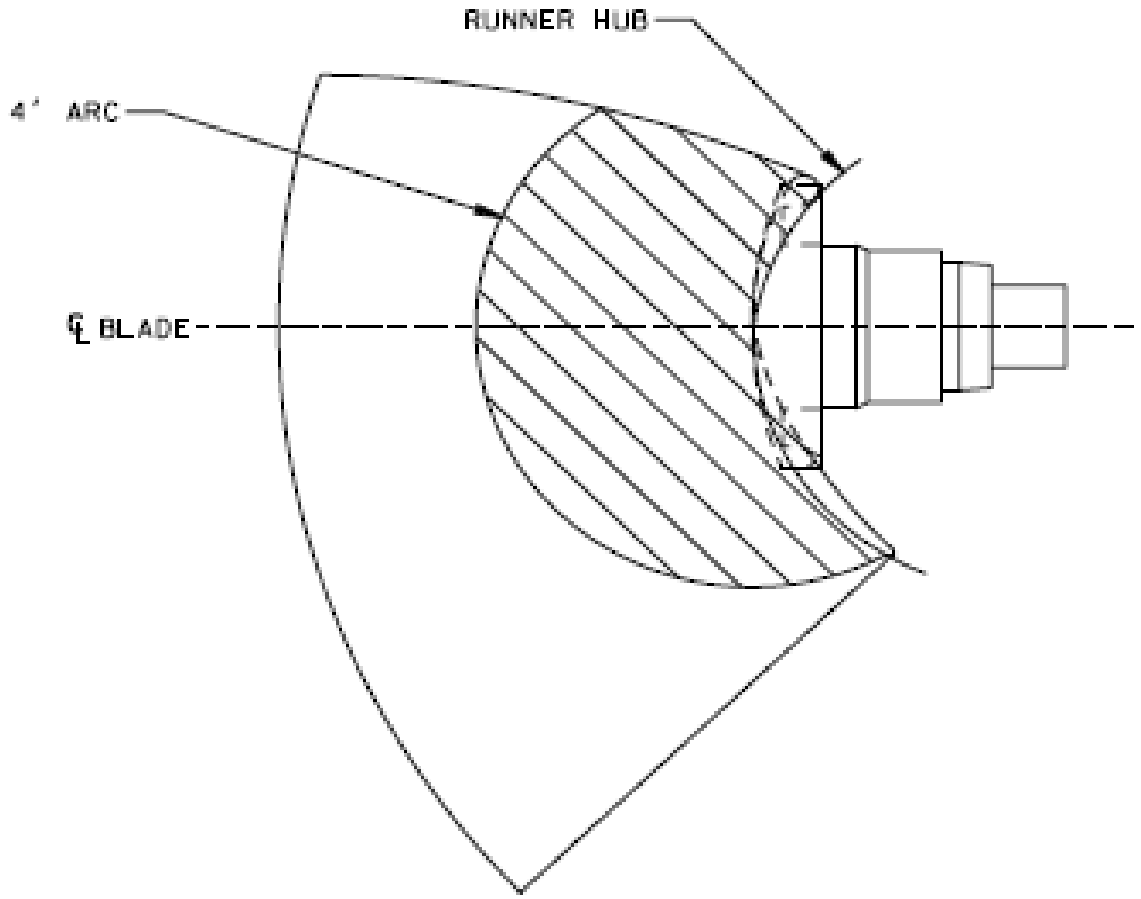
Weld Joint Design



NDE Findings

- NDE was performed on five (5) remaining blades with cracking found on all.
- COE deemed all the indications to be defects.
- Peak Hydro Services were requested to perform all repairs.
- Defects were excavated to sound material, Magnetic Particle tested (MT) and repaired.
- In process NDE was performed after every two layers deposited weld metal.

Area of Blade NDE



Blade Alignment Specifications and Techniques

- Multiple methods were used to align the blade before and during welding ensuring proper final hydraulic profile.
- Laser tracking, CAD modeling, profile templates and gauging were used.
- Measurements were taken from the blade periphery to the discharge ring and also to the hub.
- The five (5) remaining blades were measured at pre-determined locations and results averaged establishing a positional tolerance of ± 0.125 inch.
- Secondary criteria was the vent opening at the leading and trailing edges
- Twelve (12) steel discs were welded to the broken blade pressure surface and ten (10) on the stub. Laser targets were mounted to the discs.
- Laser tracking was used to monitor movement of the blade during welding and to confirm final position.
- 'Best fit' software was employed. Real time positioning data was compared to the CAD Model.

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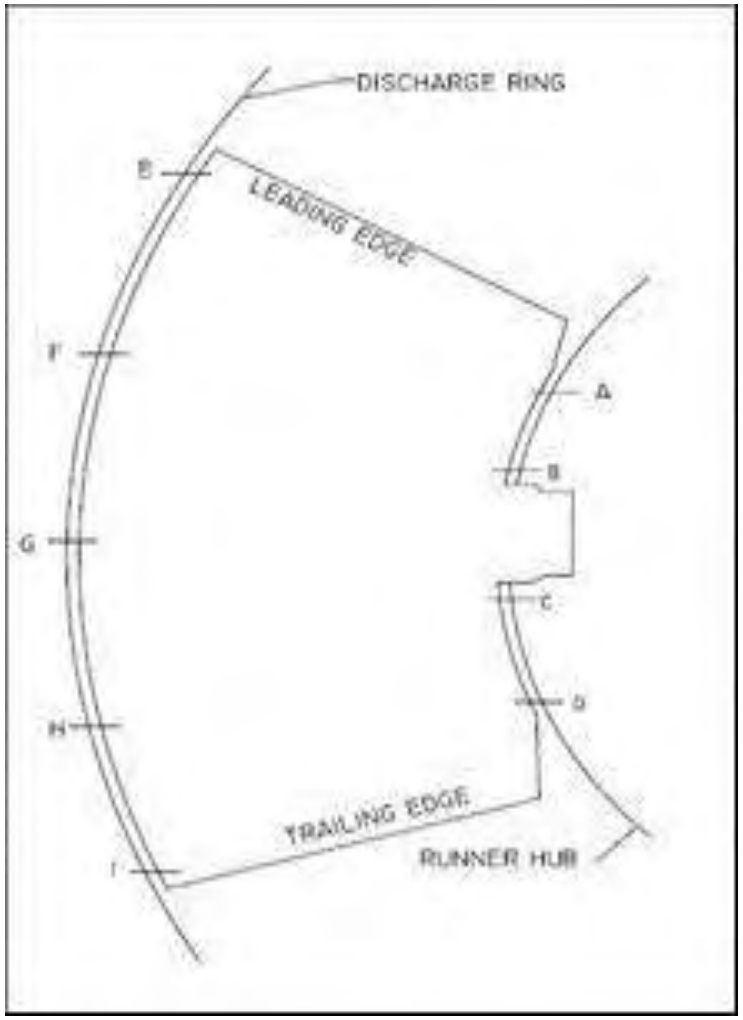
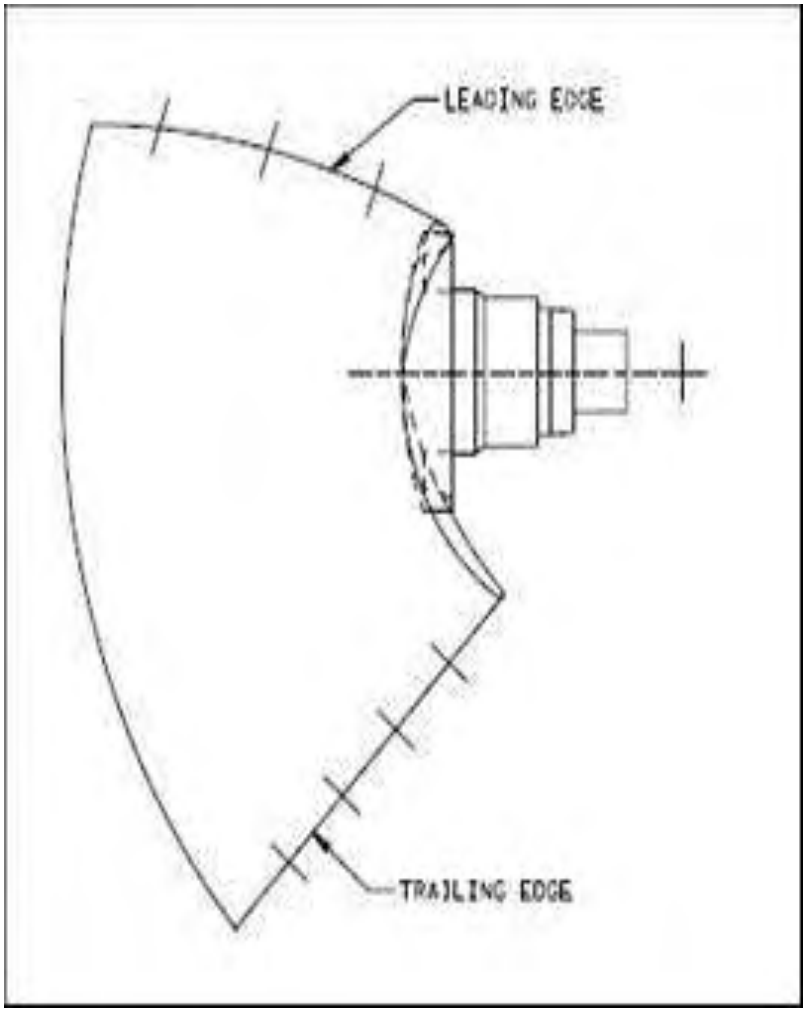
Blade control Positions





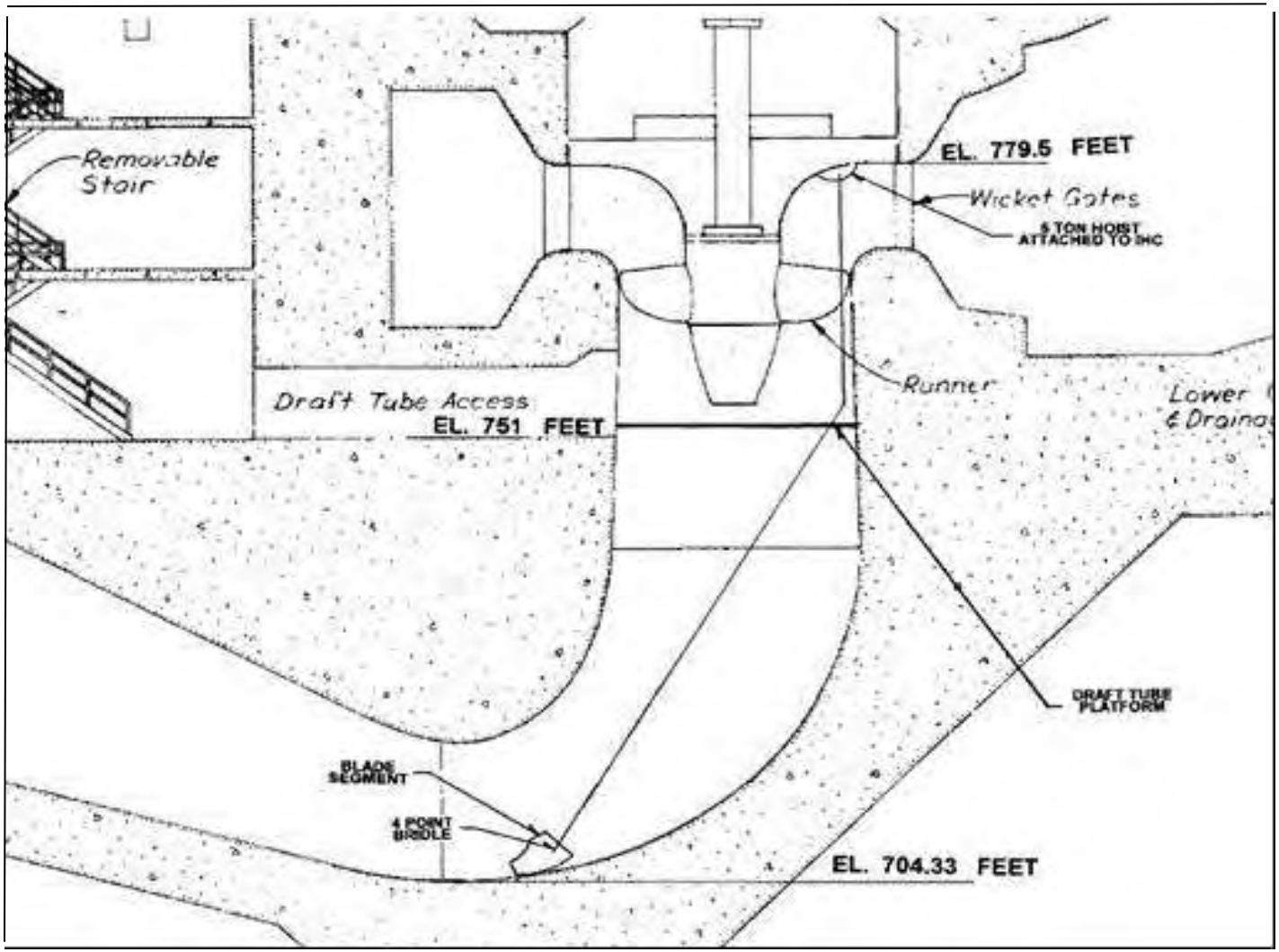
Laser Tracker

Blade Reattachment

- The blade segment was placed in the draft tube elbow by divers, the unit flooded and center draft tube door opened.
- Sections of Draft Tube Platform and equipment below the runner blades removed for access.
- Lifting lugs attached were to the Intermediate headcover.
- A six (6) Ton pneumatic hoist was attached to the main lift lug. Four (4) five (5) Ton chainfalls were placed at four (4) locations surrounding the main lug. The six (6) Ton hoist lifted the blade from the draft tube elbow to just above the draft tube platform.
- Lift was not vertical. A control lug was welded just above the draft tube platform and wide body shackle coupled to a three (3) Ton chain hoist was rigged to the lug to keep the lifting chain from hitting and damaging the remaining platform.
- The blade was then rigged to the four (4) five (5) Ton chainfalls and maneuvered into final position.

Blade in Generator Floor prior to placement into Draft Tube Elbow

Schematic of blade and rigging at the beginning of the lift



Control Lug used during Blade Lift

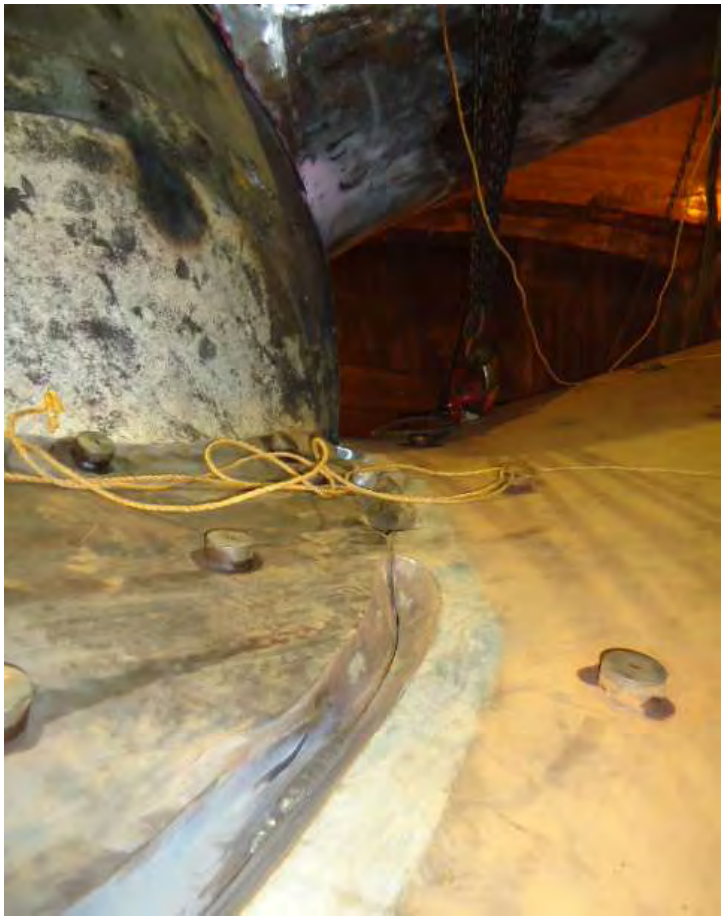
- With the blade lifted into the reattachment position and alignment verified, the weld joint was heated locally and then tack welded.
- Two (2) strong-backs were welded to the broken blade stub and the blade segment to assist shrinkage restraint during the welding process.
- On completion of fit-up resistance heaters were used to obtain the 350˚F pre-heat temperature.
- Insulation was attached on to the top and bottom surface of the blade to help temperature control.
- During the welding process the position of the blade was monitored. Vent openings, blade tip clearance and the laser were used to track the movement. Blade movement was compensated by adjusting the welding sequence.
- In process NDE was performed throughout welding of the blade. Two NDE technicians were onsite twenty four (24) hours a day once welding began. MT inspection was completed on the weld every 2nd layer.

In Process Weld Photos

View of Weld Joint after Final Fit-up seen from the Pressure Side

In Process Weld Photos

Cross Section View of Weld Joint after Final Fit-Up



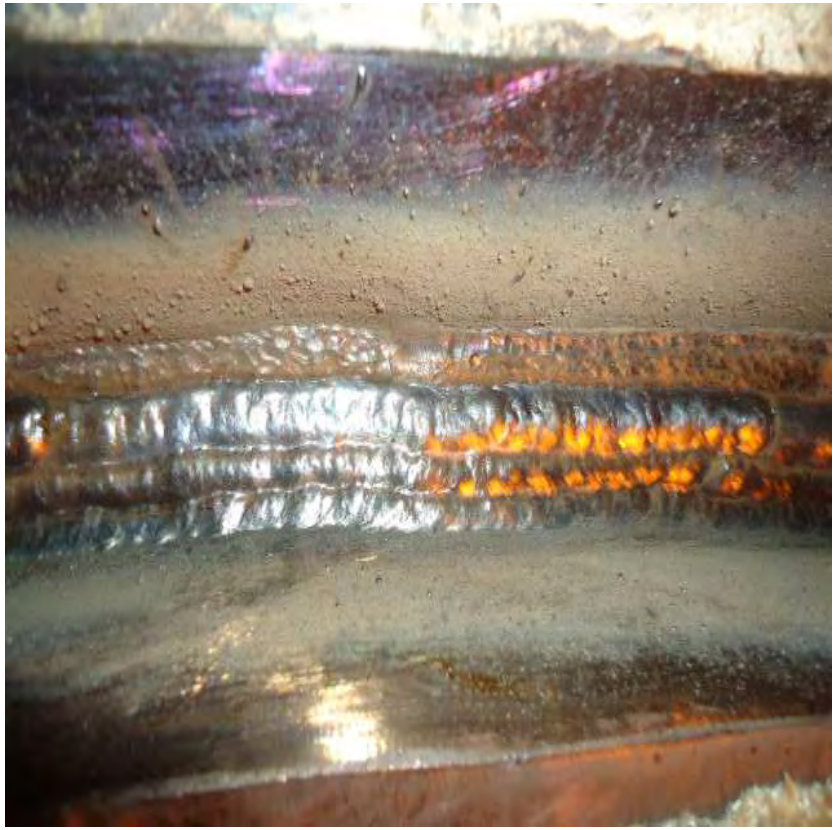
In Process Weld Photos
View of Root Beads as Deposited

Bottom Of Blade

Top of Blade

In Process Weld Photos
Weld Joint being filled –

As deposited and showing peened layer



As Deposited – Seen from Top of blade

In Process Weld Photos

Weld Deposit as seen from the bottom of the blade

Completed Weld as seen from Top of the Blade

Post Repair Procedures

- All final measurements were taken in the presence of the Government's representative.
- On acceptance of the blade position the complete weld was ground to match the blade contour with a fairness d/L of 0.01 in the direction of flow, and d/L of 0.02 perpendicular to the flow. Final surface finish was 125 µin.
- Final NDE was completed after grinding. Ultrasonic examination (UT) and a final MT inspection were completed by third party certified technicians.
- The COE performed UT inspections of the blade repair during the first year of returned service.
- Results from the first UT (available at the time of publishing) inspection showed no unacceptable indications within the repaired broken blade weld material and adjacent base material.

Conclusions

- Blade reattachment weld repairs required approximately five hundred (500) Llbs of the E81T-1 and forty (40) Lbs each of E308L and E309L electrodes.
- Preparation for reattachment, mobilization, miscellaneous repairs, blade reattachment and demobilization was completed in eighty four (84) days.
- Blade reattachment welding lasted seventeen (17) days after final fit up.
- Preheat was applied and maintained continuously during that period.
- Rapid development of procedures, project completion in a short duration demonstrated the skill and flexibility of craft labor and management.
- The project was completed ahead of schedule and the unit is in normal operation.
- The '**in place**' blade repair at Stockton was successful for the United States Army Corps of Engineers and for Peak Hydro Services